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R&D Status Report
RF Vacuum Microelectronics
Quarterly Progress Report #1
(10/1/091 - 12/31/91)

Sponsored by:

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Contractor: Honeywell Sensor and System Development Center
10701 Lyndale Avenue south
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Effective Date of Contract: September 30, 1991

Contract Expiration Date: March 31, 1993 (Baseline)

Contract Amount: Baseline $1,315,650

Option: $ 772,532

MDA972-91-C-0030

Principal Investigator: Tayo Akinwande 612/887-4481

Program Manager: David K. Arch 612/887-4404

Title of Work: **RF Vacuum Microelectronics**

92-0534

I. Executive Summary

Program Objective: Demonstrate an edge emitter based vacuum triode with emission current density of 10 μA/μm at less than 250 V which can be modulated at 1 GHz continuously for 1 hour.

Key Achievements (this reporting period)

- Identified two sources of emitter burn-out and have developed emitter designs to overcome this effect.

- Demonstrated controlled deposition of high resistivity (>1 MΩ/square) TaN for use as current limiting resistors during emitter burn-in.

II. Milestone Status (FY 1992 Milestones)

	Completion Date	
1. Field Emitter Development		
Test Structure Design Complete	12/91	1/92
Determine Workable Emitter Structure	3/92	3/92
2. Process Development		
High Resistivity Thin Film Resistor	4/92	4/92
3. Triode Development		
-Triode Design Complete	4/92	5/92
-Demonstrate Reliable/Uniform Current Emission	7/92	8/92
-Demonstrate Modulated/Edge Emitter Triode	8/92	9/92

III. Technical Progress

Efforts during this reporting period were focussed on the analysis of results from the literature and on results for devices fabricated at Honeywell previously so as to develop approaches for obtaining uniform current emission from a thin film edge emitter without burnout. Observation of the emitter edge during emission on Honeywell's thin film edge devices (these devices were not fabricated on this program) show parts of the edge spontaneously burning out with a concomitant sharp drop in emission current. However, after a period of time (typically 30 minutes), the emission current builds up again indicating another region of the edge is emitting. This cycle often repeats itself several times before the entire edge burns out. The burned out portions of the edge are typically micron-sized and form systematically down the edge of the emitter. We also observe, on occasion, that the burnout does not originate from the edge but from the middle of the film.

The above observations lead us to speculate on the causes of the burn-out:

- Electron heating of the anode (from the emission current) resulting in desorption of positive ions which are accelerated to the emitter by the electric field. This results in additional heating of the emitter and the resultant burnout.

- Current concentration at localized microtips on the emitter. This leads to very high current densities with the resulting temperature rise and subsequent melting of the area adjacent to the microtip.

We believe that both processes are occurring with the latter being dominant. This belief is supported by the gradual burnout of the edges until the whole edge stops emitting current.

The conclusions drawn from our device analysis suggest several approaches to developing an edge emitter which is essentially immune to burnout and has uniform emission characteristics. These approaches include:

- Using comb edges with high valued resistors in series to act as resistive voltage drops.

- Using comb edges with non-linear resistors or current sources that presets the current per comb.

- Using comb edges with non-linear resistors which can be bypassed after the edges have developed.

- Developing a process that will smooth the thin film edge after the sacrificial layer is removed, e.g., electropolishing.

The first approach was commonly used in the early days of power BJTs and is still in use because of experienced problems of premature burnout of devices.

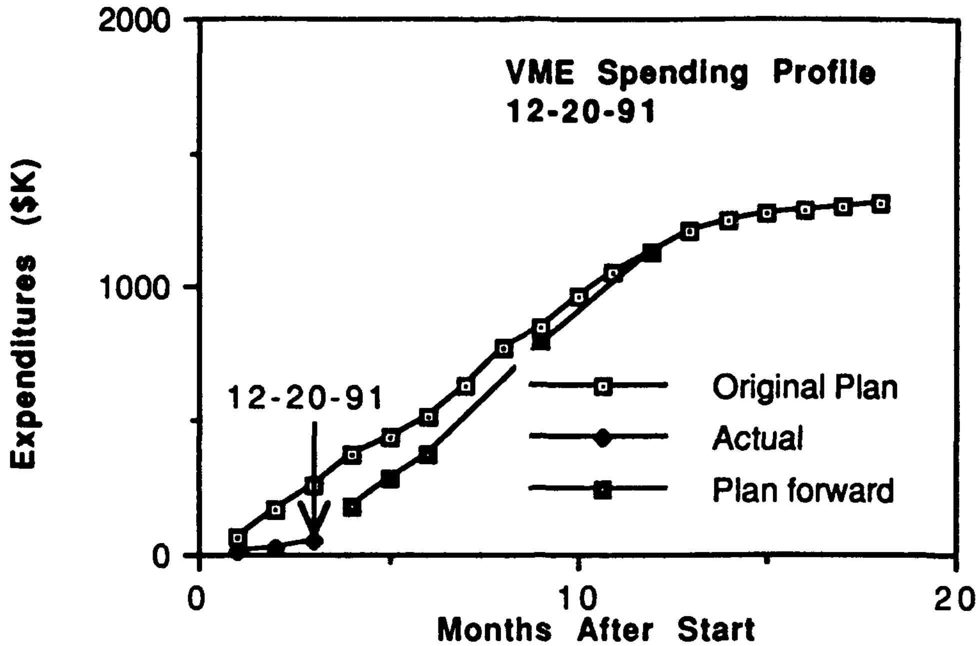
We are implementing the above approaches in several emitter designs which will be fabricated in the next reporting period.

Concurrent with the design development has been the development of a suitable thin film resistor. Our initial estimates indicate that the material must have a resistivity of 1 to 10 MΩ/square. Three candidates are being explored for this application; tantalum nitride, polysilicon and a cermet material such as silicon oxide doped with chrome or gold. Our initial experiments with TaN indicate many of the necessary thin film properties for the edge emitter application including controllable resistivity (by controlling the nitrogen concentration) and process compatibility. TaN will be used in the first emitter fabrication runs. Lightly doped polysilicon is also being explored because of its high resistivity and because its resistivity is voltage dependent, the resistance increasing with increasing bias. We have ordered a lightly doped polysilicon sputtering target and will begin depositing and characterizing thin films of the material during the next reporting period.

Plans for next reporting period:

- Complete test structure designs for edge emitters (1/92)
- Fabricate first edge emitters (diodes) with TaN current limit resistors (2/92)
- Demonstrate high resistivity polysilicon thin film (3/92)
- Complete first analysis of mechanical stability of triode device structure using ANSYS (3/92).

IV. Fiscal Status



Expenditures this quarter	$ 58,159 (12/20/91)
Total expenditures to date	$ 58,159
Projected expenditures:	
1/92 - 3/92	$ 322,856
4/92 - 6/92	$ 408,509
7/92 - 9/92	$ 351,862
Total Projected Cost for FY92	$1,141,387.

V. Problem Areas

- The University of Minnesota subcontract to look at vacuum encapsulation techniques for vacuum triode isolation is being held up by our ACO due to lack of sole source justification. A request has been made to Bert Hui, DARPA, to submit a letter to the ACO, justifying the choice of the University of Minnesota to conduct this effort.

- At present we are behind the spending plan as originally submitted to DARPA for this program. The primary reason is that we were waiting for device results from another program to guide us in the proper directions for initial designs of the edge emitter. Because of a catastrophic failure of a critical piece of process equipment (since repaired) in the process lab, those devices were not completed until near year end. We felt it was in the best interests of the VME program to wait for these results before proceeding with the design. We anticipate recovering this schedule slip over the next 9 months and will be back on plan 1 October 1992.